5. CHECKS ON THE GENERAL LEVEL OF PMP

5.1 Introduction

All probable maximum precipitation estimates involve some degree of uncertainty. Decisions leading to a level that provides safety, while not introducing unrealistically large estimates of precipitation amounts, requires experience and meteorological judgment. Guidance for such decisions includes evaluating maximum observed precipitation depths, and meteorological studies of storm characteristics such as moisture sources and storm mechanism. PMP must exceed the envelop of maximum observed values. For most regions, nature has not yet given us the biggest storm; rainfalls occasionally exceed the previous maximum from over 50 years of record by factors of 2 or 3.

In this chapter PMP estimates are compared with known maximum precipitation amounts in the Southwest States. We also show comparisons of the general level of PMP in this study with values in an earlier study and with PMP estimates in adjoining regions. In chapters 2 and 3 we pointed out how convergence and orographic PMP index maps compare with similar maps in HMR Nos. 43 and 36 for adjoining regions to the north and west, respectively. These discussions will not be repeated here. Rather, the general level of total PMP will be compared. Comparisons are also made with 100-yr rainfall and with some statistically estimated PMP values. Finally, we evaluate the rain potential from a hypothetical tropical cyclone, one that has the most extreme characteristics for producing rainfall for the Southwest States that such a storm might have.

5.2 Comparisons with Greatest Known General-Storm Areal Rainfalls

From a catalog of greatest known areal rainfall depths (Shipe and Riedel 1976) the greatest depths for various portions of the study region were extracted for the winter, spring, summer and fall seasons. Four standard areas: 100, 500, 1,000 and 5,000 mi^2 (259, 1,295, 2,590 and 12,950 km^2) for 6, 12, 18, 24, 48, and 72 hours were considered.

Table 5.1 lists the storm date, latitude and longitude of rainfall center, general location by section of the State, and the ratio of observed to general-storm PMP for the month of the storm for the selected area sizes. Of these comparisons, the September 1970 rainfall center in southwestern Colorado and southeastern Utah stands out with a high ratio of observed to PMP of 0.88 for 6 hours over 100 mi^2 (259 km^2). [The local-storm PMP (chapter 4) at this location exceeds the general-storm values, for this size area and duration, giving a ratio of observed to PMP of 0.69.] The more intense rainfall center of the September 1970 storm in central Arizona (where the ratios of observed to PMP are smaller than at the northern center) is not as rare an event. Comparisons with mean annual precipitation and other rainfall indices also lead to this conclusion.

Examination of the variation of the ratios of observed to PMP with duration shows the ratios decrease with increasing duration. This trend is considered reasonable in that nature has given us a larger number of extreme short-duration storms than longer ones over any given basin. There are rare

Table 5.1.--Comparison of storm areal rainfall depths with general-storm PMP for the month of the storm

Date	Latitude-longitude (of center)		General location	Area mi^2	(km^2)	Duration (hrs) 6	12	18	24	48	72
								obs/PMP			
11/25-28/05	34°13'	112°45'	Central Ariz.	100	(259)	.54	.38	.35	.33	.27	
				500	(1295)	.60	.40	.38	.36	.31	
				1000	(2590)	.60	.40	.38	.37	.34	
2/1-5/07	41°45'	115°25'	NE Nev.	100	(259)	.60	.68	.52	.59	.50	.51
				500	(1295)	.62	.67	.50	.56	.48	.49
				1000	(2590)	.61	.68	.64	.63	.54	.55
12/14-17/08	37°30'	108°30'	SW Colo.	100	(259)	.48	.53	.50	.53	.50	.52
				500	(1295)	.50	.52	.53	.53	.51	.53
				1000	(2590)	.50	.51	.50	.50	.47	.50
				5000	(12950)	.60	.58	.60	.55	.53	.55
12/14-17/08	34°22'	111°25'	Central Ariz.	5000	(12950)	.35	.44	.35	.35	.38	.36
8/28-9/2/09	40°00'	111°00'	N Utah	100	(259)	.34	.42	.34	.47	.39	.37
				500	(1295)	.32	.39	.31	.42	.34	.32
				1000	(2590)	.33	.39	.31	.40	.32	.31
				5000	(12950)	.31	.34	.26	.34	.27	.26
10/4-6/11	37°49'	107°40'	SW Colo.	100	(259)	.53	.64	.65	.60	.46	
				500	(1295)	.36	.45	.47	.43	.33	
				1000	(2590)	.39	.47	.52	.49	.38	
				5000	(12950)	.40	.41	.48	.47	.37	
4/5-10/26	34°51'	112°00'	Central Ariz.	100	(259)	.52	.41	.41	.37	.30	
				500	(1295)	.51	.43	.44	.41	.32	
				1000	(2590)	.51	.45	.47	.42	.33	
				5000	(12950)	.39	.36	.37	.35	.27	
2/11-17/27	34°19'	111°27'	Central Ariz.	100	(259)	.40	.39	.36	.38	.45	.48
				500	(1295)	.43	.39	.38	.39	.47	.52
				1000	(2590)	.40	.34	.35	.36	.44	.42
				5000	(12950)	.34	.28	.28	.29	.37	.43

Table 5.1.--Comparison of storm areal rainfall depths with general-storm PMP for the month of the storm--Continued

Date	Latitude-longitude (of center)		General location	Area mi^2	(km^2)	Duration (hrs) 6	12	18	24	48	72
						obs/PMP					
10/11-14/28	40°36'	110°24'	N Utah	100	(259)	.43	.50	.57	.48	.34	.36
				500	(1295)	.37	.44	.49	.42	.30	.33
11/12-17/30	41°45'	115°25'	NE Nev.	100	(259)	.55	.63	.49	.60	.55	.52
				500	(1295)	.50	.58	.45	.55	.51	.48
				1000	(2590)	.48	.51	.40	.51	.47	.44
2/1-3/36	40°36'	111°42'	N Utah	100	(259)	.37	.22	.17	.28		
				500	(1295)	.35	.20	.16	.26		
2/27-3/4/38	34°57'	111°44'	Central Ariz.	100	(259)	.49	.57	.50	.43	.31	.32
				500	(1295)	.58	.66	.60	.52	.38	.38
				1000	(2590)	.63	.70	.64	.55	.39	.41
				5000	(12950)	.56	.60	.46	.40	.28	.35
2/27-3/4/38	37°30'	112°30'	S Utah	100	(259)	.55	.38	.40	.50	.37	.38
				500	(1295)	.62	.41	.42	.46	.34	.37
				1000	(2590)	.77	.43	.43	.47	.35	.36
5/4-9/43	40°21'	106°55'	N Colo.	100	(259)	.20	.17	.15	.17	.12	.14
				500	(1295)	.22	.18	.15	.16	.13	.15
				1000	(2590)	.25	.18	.15	.16	.13	.16
				5000	(12950)	.23	.17	.15	.15	.13	.16
5/31-6/6/43	40°36'	111°36'	N Utah	100	(259)	.27	.25	.30	.27	.24	.23
				500	(1295)	.28	.27	.30	.27	.25	.23
				1000	(2590)	.27	.28	.32	.28	.26	.24
				5000	(12950)	.28	.30	.34	.32	.28	.25
10/27-29/46	37°30'	114°00'	SW Utah	100	(259)	.63	.44	.37	.80	.61	.55
				500	(1295)	.52	.35	.29	.66	.49	.44
				1000	(2590)	.43	.28	.23	.51	.38	.33
				5000	(12950)	.35	21	.17	.42	.30	.26

Table 5.1.--Comparison of storm areal rainfall depths with general-storm PMP for the month of the storm--Continued

Date	Latitude-Longitude (of center)		General location	Area		Duration (hrs)					
				mi^2	(km^2)	6	12	18	24	48	72
						obs/PMP					
8/25-30/51	34°07'	112°21'	Central Ariz.	100	(259)	.35	.41	.41	.41	.55	.56
				500	(1295)	.40	.47	.43	.46	.58	.59
				1000	(2590)	.45	.48	.46	.48	.58	.59
				5000	(12950)	.30	.34	.38	.40	.44	.47
9/3-5/70	37°38'	109°04'	SW Colo.	100	(259)	.88	.81	.71	.63	.53	
			SE Utah	500	(1295)	.80	.73	.64	.58	.49	
				1000	(2590)	.81	.74	.64	.59	.52	
				5000	(12950)	.49	.46	.47	.46	.39	
9/3-5/70	33°49'	110°56'	Central Ariz.	100	(259)	.63	.58	.56	.54	.43	
				500	(1295)	.54	.47	.45	.45	.36	
				1000	(2590)	.50	.48	.48	.47	.38	
				5000	(12950)	.52	.50	.51	.47	.37	

occasions when rains repeat or are continuous over a basin for a 3-day period. Continuation of an extreme inflow of moisture for longer durations is less likely, but yet a possibility. The August 1951 storm is an example of an event where a high level of moisture inflow and a continuation of the mechanism for causing rain produced an extreme rainfall event of 3-day duration.

Figures 5.1 and 5.2 show scatter diagrams for two sets of data taken from table 5.1. The comparison between maximum observed 100-mi^2 (259-km^2) 24-hr storm amounts and corresponding PMP estimates is shown in figure 5.1. Storms whose observed amounts come within 50% of PMP are identified. Note that for 24 hours duration, a southwest Utah storm in October 1946 more closely approaches PMP than any other storm. Figure 5.2 shows the comparison of known greatest rainfall amounts to PMP for 5,000 mi^2 (12,950 km^2). Only one storm comes within 50% of PMP. The validity of the trend toward lower ratios with larger areas is supported by the fact that fewer large-area storm depths have been recorded than small-area storm depths.

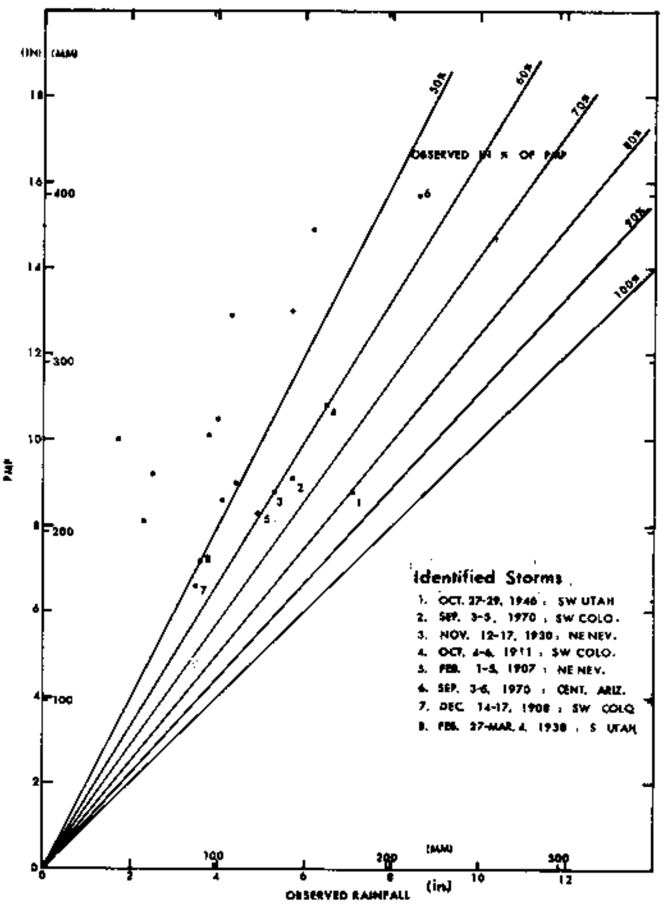


Figure 5.1.--Comparison between observed rainfall depths and general-storm PMP for 100 mi^2 (259 km^2) 24 hr.

5.3 Comparisons with Greatest Known Local-Storm Rainfalls

Local-storm PMP estimates were determined for the location of the 39 major local storms given in table 4.1. This does not include the four long-duration California storms. A scatter diagram of maximum observed total-storm amount vs. the PMP estimate for that duration is shown in figure 5.3.

Envelopment of local-storm data by PMP is less than that for general-storm data. The Campo and Chiatovich Flat, California rains come within 15% of the local-storm PMP estimates. Because of the doubt that has been given to the Palmetto, Nev. observation (U.S. Weather Bureau 1960), a question mark has been placed at this point in figure 5.3.

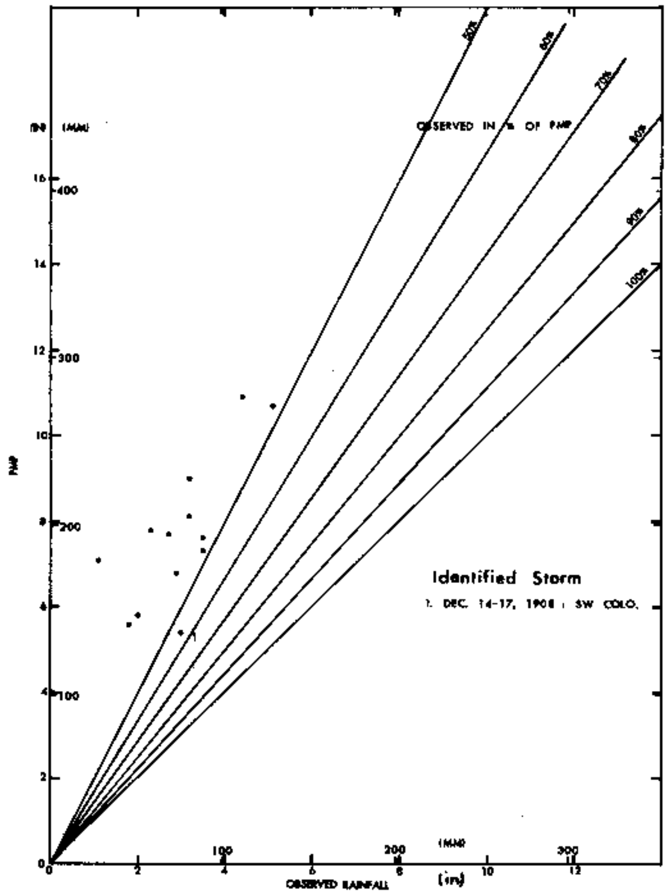
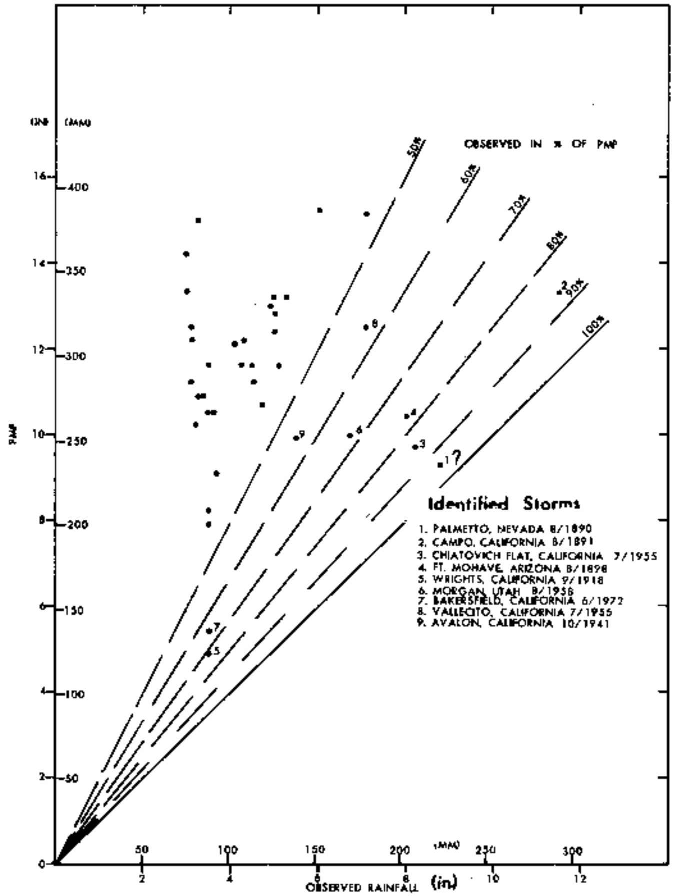


Figure 5.2.--Comparison between observed rainfall depths and general-storm PMP for 5000 mi^2 (12,950 km^2) 24 hr.



5.3.--Comparison between observed rainfall depths from local storms and local-storm PMP for the duration of the storm.

5.4 Comparisons with Estimates from a Previous Study

Technical Paper No. 38 (U.S. Weather Bureau 1960) gives all-season PMP estimates for the Western States for durations to 24 hours and areas up to 400 mi^2 (1,035 km^2). For the Southwest the 24-hr PMP of Technical Paper No. 38 is largely controlled by extreme summer thunderstorms. PMP from the present study for both the local storm and the general storm were computed for 10 mi^2 (26 km^2) on a 1° latitude-longitude grid (fig. 5.4). The upper value at each point is the general-storm 24-hr PMP. The 6-hr local-storm PMP exceeds the 24-hr general-storm value at many points. No attempt was made to draw an analysis of the data because of important topographic effects between the grid points.

Figure 5.5 compares the grid point amounts from Technical Paper No. 38 with the larger of the amounts shown for each point in figure 5.4. Although figure 5.5 shows considerable scatter there is general agreement that high estimates in the earlier study are also high in the present study. The cluster of points having PMP less than 16 inches (406 mm) in the 1960 study are in general from the less-orographic locations, whereas the more widely scattered values greater than this amount come from mountainous locations.

For 10 mi^2 (26 km^2) 24 hours, it is apparent from figure 5.5 that PMP from this study generally is less than the PMP estimated in 1960, and that there is a greater reduction for high PMP values (mountainous points) than for low values (less-orographic points). The level of PMP is partially a function of the amount of detail and data included in each study. The 1960 study covered a large region, while the present study considered more detail over an area about one-third as large. More conservative (higher) PMP estimates tend to result from broadscale analyses. Interpretation of figure 5.5 should not be applied to other durations, area sizes, or regions covered by Technical Paper No. 38.

5.5 Comparisons with 100-yr Return Period Rainfalls

Comparison was also made between PMP estimates and published 100-yr 24-hr rainfall values in the Western United States (Miller et al. 1973). In the frequency studies an effort was made to utilize all available data, but many gaps remained. Multiple regression screening techniques were used to interpolate between data points. These techniques placed greater emphasis on meteorological factors and topography than previous frequency studies for this region.

The frequency data are heavily weighted by thunderstorm rains; therefore, the greater of the local 6-hr PMP and general-storm PMP for 24 hours over 10-mi^2 (26 km^2) was compared to 100-yr 24-hr rainfall. Figure 5.6 shows a plot of 100-yr values vs. PMP for points on a 1° latitude-longitude grid covering the Southwest States. Most of the 100-yr amounts appear to be about 20 to 35% of the PMP. The results shown in figure 5.6 are not necessarily the same as would be found with other area sizes, durations or regions.

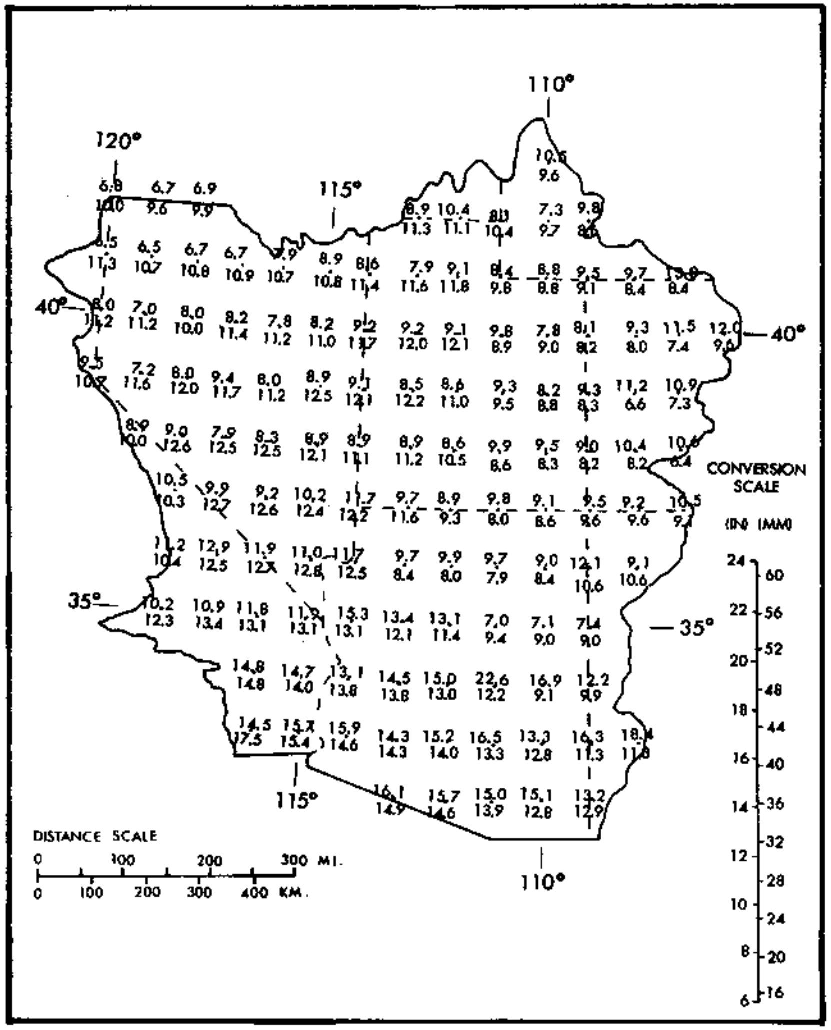


Figure 5.4.--General-storm PMP for 10 mi^2 (26 km^2) 24 hr in inches (upper number) and local-storm PMP for 10 mi^2 (26 km^2) 6 hr in inches (lower number) at 1° grid points.

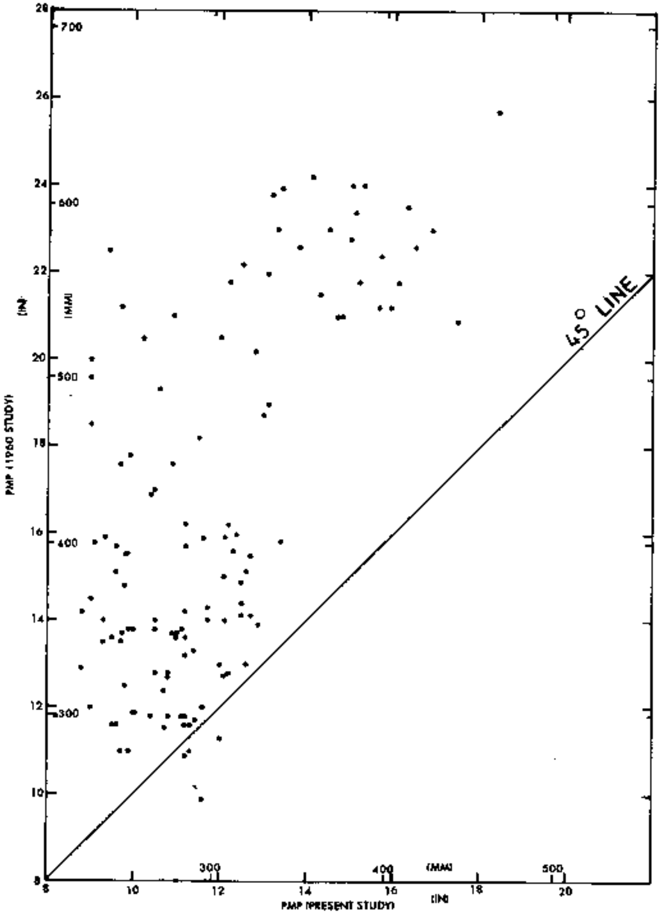


Figure 5.5.--Comparison between PMP from Technical Paper No. 38 (U. S. Weather Bureau 1960) and from this study. PMP values (present study) are the larger of the general- or local-storm amounts for 10 mi^2 (26 km^2) at 1° grid points.

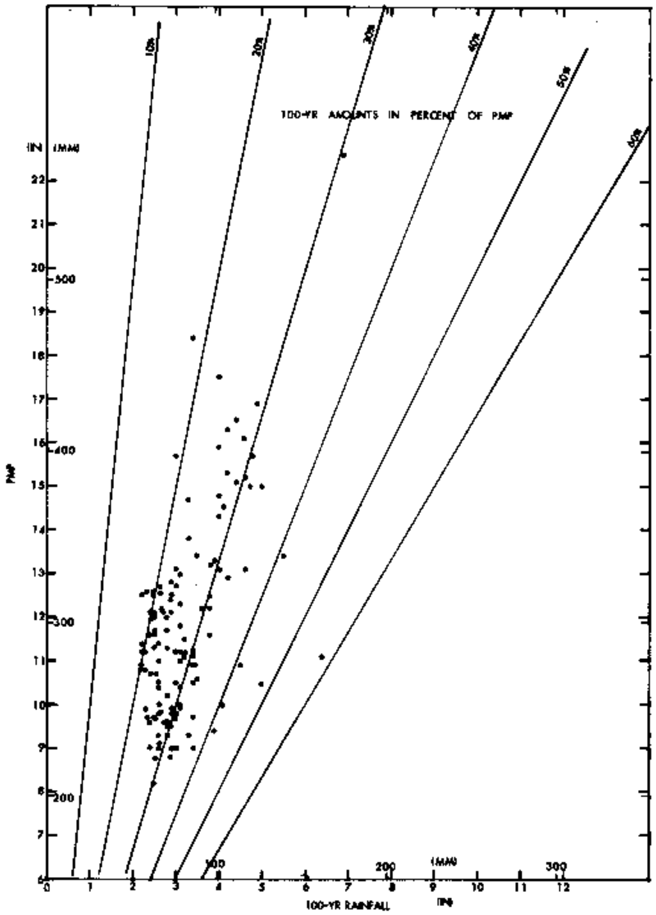


Figure 5.6.--Comparison between 100-yr rainfall (Miller et al. 1973) and PMP. PMP values are the larger of general- or local-storm amounts for 10 mi^2 (26 km^2) 24 hr at 1° grid points.

5.6 Mapped Ratios of 100-yr to PMP Values Over the Western States

Mapped ratios of 100-yr 24-hr rainfall to 24-hr PMP over a 1° latitude-longitude grid for most of the Western States and a portion of the Central States are shown in figure 5.7. For the Western States, PMP values came from this study, HMR Nos. 36 and 43. The Central States values are from HMR No. 51 (Schreiner and Riedel 1978). In figure 5.7, the larger of the local-storm and general-storm PMP estimates was used in the Western States.

Frequency data came from NOAA Atlas 2 (Miller et al. 1973). Although the volumes of this Atlas cover each of the Western States, they also include the eastern portions of those states along the Continental Divide. The eastern portions of Wyoming, Colorado and New Mexico enabled us to make a comparison of 100-yr 24-hr rainfall to PMP at a few points east of the Divide as shown in figure 5.7. Therefore, the comparisons for the Central States shown in figure 5.7 have been limited to these state boundaries.

Points where the 6-hr local-storm-PMP controls for 24 hours have been underlined in figure 5.7. Dominance of the local-storm PMP, through much of the Southwest extending into eastern Oregon and Washington and southern Idaho, is apparent. Essentially, the local-storm PMP controls in the less-orographic portions of the Western United States while the general storm prevails over the more mountainous regions for this area size.

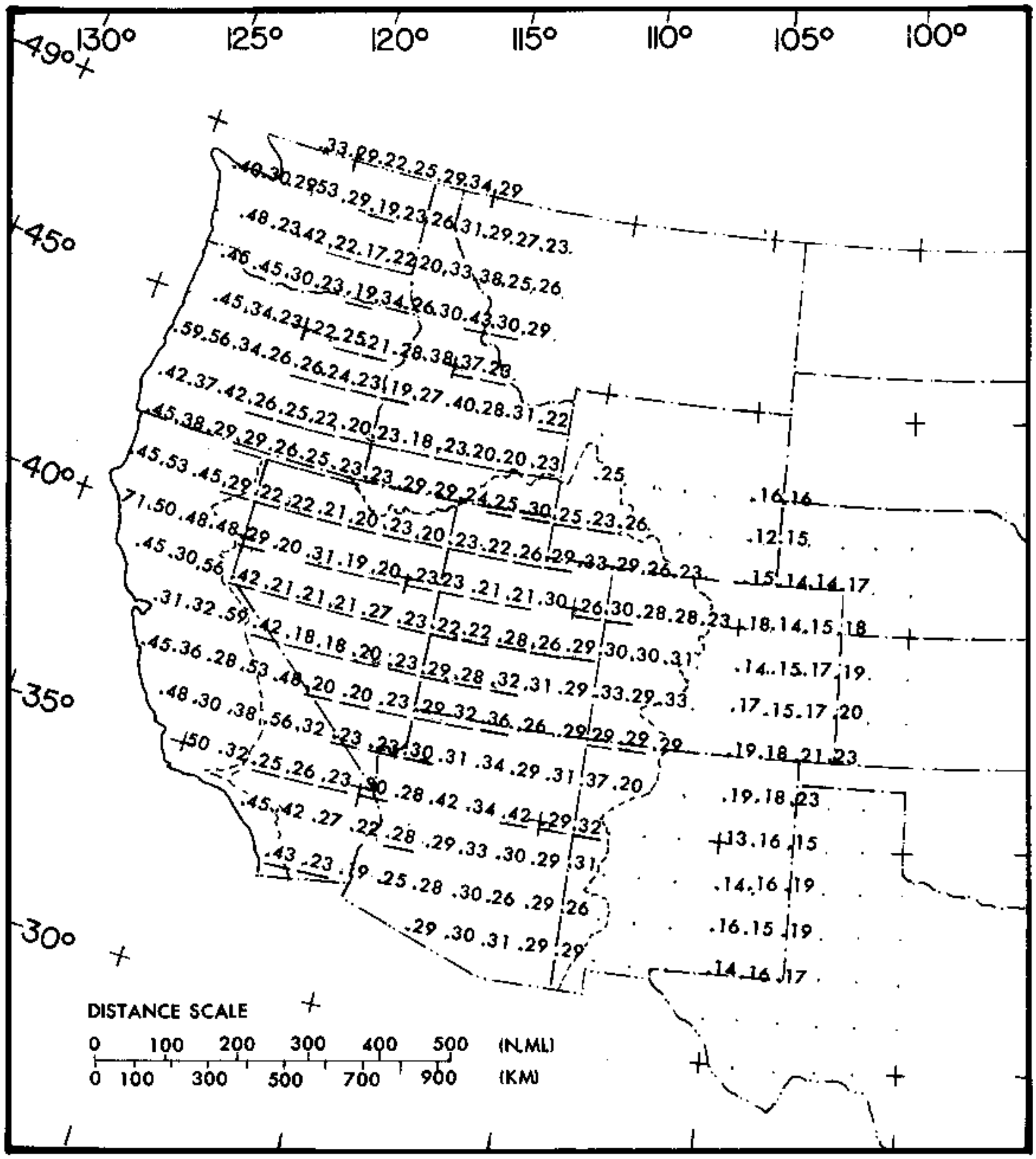


Figure 5.7.--Ratios of 100-yr point rainfall (Miller et al. 1973) to highest PMP for 10 mi^2 (26 km^2) 24 hr. Underlined ratios are points where 6-hr local-storm PMP controls. East of 105th meridian PMP taken from eastern states study (Schreiner and Riedel 1978).

The range of ratios shown in figure 5.7, 0.28 to 0.71 in the Pacific drainage of California, 0.17 to 0.59 in the Northwest, 0.18 to 0.56 in the Southwest, shows apparent consistency between the Northwestern and Southwestern Regions. East of the 105th meridian, the ratios range between 0.12 and 0.23. The trend in ratios that appears in going from the west coast to east of 105°W is what one might expect. There is a tendency for the ratios to decrease eastward from the Pacific coast and then increase again on windward slopes. This tendency is consistent with the results for similar ratios in HMR Nos. 36 and 43.

The ratios shown on figure 5.7 should not be used for basin PMP estimates. Variation in terrain features between 1° grid points could give a considerably different basin average PMP; i.e., because of topographic variations, the ratios are not necessarily representative of the area surrounding the grid point.

5.7 An Alternate Approach to PMP

An additional study was made of the variation in ratios of 100-yr rainfall to PMP estimates for the region most similar to the Southwest States that also had detailed estimates of both the precipitation criteria. This region is the Columbia River drainage east of the Cascade Divide. A conclusion of the study was that the 100-yr to PMP ratio should vary with the raininess of the location, and that a 90% envelope of a grid of ratios for the Northwest varies from 0.25 for a location with a MAP of 10 inches (254 mm) (dry region) to a ratio of 0.50 for a location with a MAP of 70 inches (1,780 mm) (wet region).

The curvilinear relation between 100-yr/PMP ratios and MAP (not shown) from the Columbia River drainage east of the Cascade Divide was used to estimate PMP for the Southwestern States over a 1° latitude-longitude grid[1]. Figure 5.8 gives the ratios of PMP by this alternate approach (100-yr/PMP vs. MAP) to the general-storm PMP of this study. It is important to point out that PMP estimates obtained by the ratio of 100-yr to PMP is not a recommended method for determining PMP. In any case, such a method includes transposition of an index relation without modification. Considerations such as the strength of the inflow wind and moisture potential would have an effect on the ratio of PMP to a lesser storm, such as the 100-yr precipitation, and the relation of the ratio to MAP.

The ratios can, however, be used as a check on the general level of the PMP estimates assuming we know the general level of PMP to the north, we have confidence in the 100-yr precipitation estimates, and accept the transposition of the index relation. Figure 5.8 indicates that the PMP estimates based on the transposed 100-yr/PMP relation vary from a low of 67% of the estimates in this study to a high of 223%. However, more than 60% of the values are within 25% of this report's PMP values. We believe this variation is acceptable, taking into account use of a transposed relation and unknowns in the generalized charts of mean annual precipitation and frequency values as well as in PMP.

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[1]Charts used were for MAP and NAP referenced in section 3.1.3, and those for Nevada (Hardman 1965) and southern California (Rantz 1969).

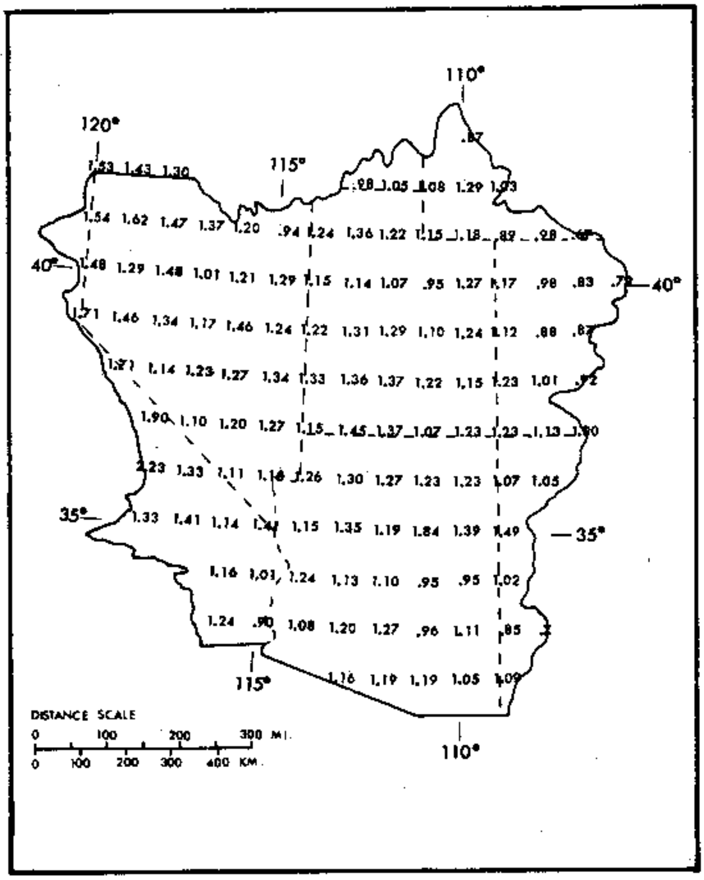


Figure 5.8.--Ratios of PMP determined from an alternate approach (see section 5.7) to that of this study for 10 mi^2 (26 km^2) 24 hr.

5.8 Statistical Estimates of PMP

5.8.1 Background

A general formula for hydrologic frequency analysis (Chow 1951) demonstrated that the difference between various theoretical distributions is the value of K in the following formula:

$$x_T = \overline{x} + KS_n \qquad (5.1)$$

where x_T is the rainfall for return-period T, $\overline{x}$ is the mean of a series of annual maximum station precipitation, n is the sample size, and S_n is the standard deviation. Hershfield (1961) substituted the maximum observed rainfall (x_{max}) for x_T. K is then the number of standard deviations to add to $\overline{x}$ to obtain x_{max}. Using selected "world-wide" data, Hershfield originally adopted 15 as maximum K value for a statistical estimate of PMP.

Hershfield (1965) introduced a variable K-factor (K_m) related not only to the mean of the annual maximum rainfall but also to the duration. This modified relation in which K varies with rainfall magnitude was used in a statistical approach to PMP for the Southwestern States. The modified formula is:

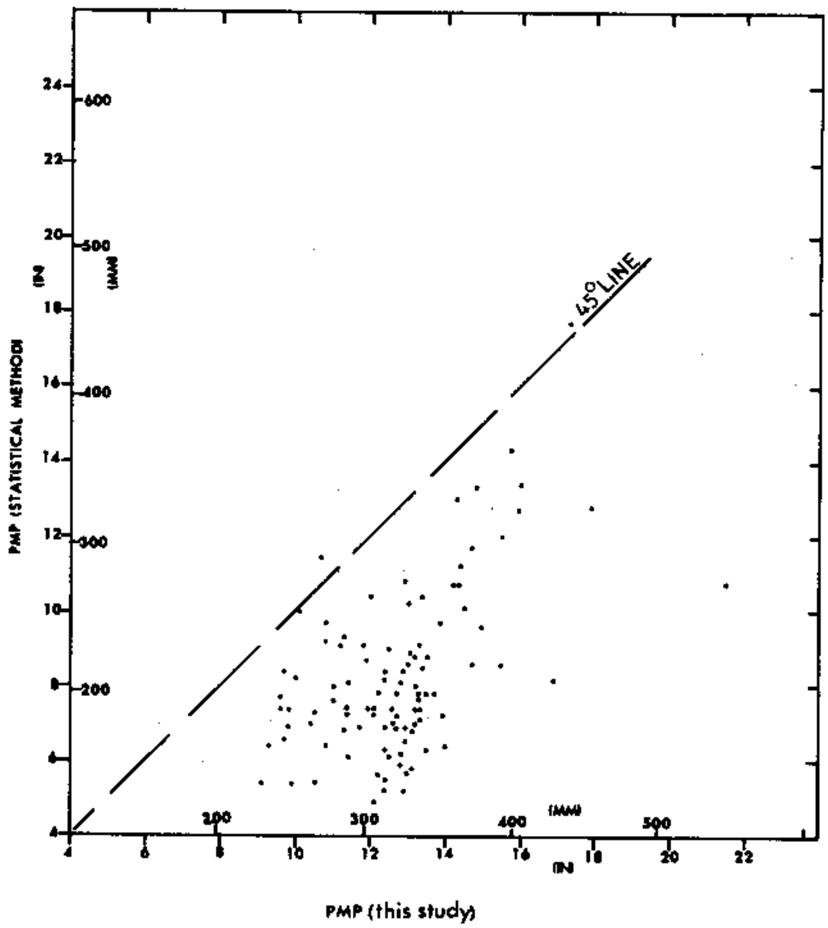
$$X_m = \overline{x} + K_m S_n \qquad (5.2)$$

5.8.2 Computations

Computations of statistical PMP were made from data used in the rainfall-frequency analyses for the Western States (Miller et al. 1973). These data consisted of station values of mean and standard deviation of the annual maximum 24-hr rains. The variation of K as a function of the mean of the annual maximum 24-hr rains was taken from Hershfield's study (1965). The values of K necessary to cover the Southwestern States were mostly between 14 and 19. Arid regions have higher values of K than the worldwide average of 15. Given the K factors, one need only use the mean ($\overline{x}$) and standard deviation (S_n) from the series of annual maxima to solve equation 5.2.

5.8.3 Discussion

The highest PMP from the larger of general- and local-storm estimates for 24 hr and 10 mi^2 (26 km^2) were compared to statistical PMP computed from equation 5.2 at 98 stations in the Southwestern Region with rainfall records for 50 years or longer. Comparison of the two sets of values is shown in figure 5.9. Considerable scatter is apparent with the statistical PMP being less than the PMP from this report for all but two stations. The same results have been found for comparisons in other regions (World Meteorological Organization 1973).



5.9.--Comparison between statistical PMP (Hershfield 1965) and the highest PMP for 10 mi^2 (26 km^2) 24 hr at stations with records exceeding 50 years.

Hershfield (1961, 1965) recommended some adjustments to the data. The first was an adjustment of $\overline{x}$ and S_n for a rare event, called an outlier. The ratio of the mean of the series excluding the outlier to that with the outlier could result in a downward adjustment to the mean by as much as 20%. Similarly, the ratio of S_n excluding the outlier to that with the outlier could bring about an adjustment to S_n of more than 50% depending on the record length.

A second adjustment normalizes daily data to 24-hr data. This factor can vary between 1.00 and 1.13 depending on the number of fixed time intervals considered in obtaining the maxima. Neither of these two adjustments was applied to the data in figure 5.9.

Another adjustment makes allowances for lengths of record less than 50 years. Adjustments up to 5% for the mean and up to 30% for S_n occur for records of only 10 years. In the present study only stations having records for 50 years or more were considered, so this adjustment was unnecessary.

Inclusion of the adjustments mentioned by Hershfield probably would have changed some of the points plotted in figure 5.9, but it is doubtful that they would have had much effect on the broad-scale scatter.

It is possible that the scatter would be reduced somewhat if the K factors had been averaged regionally prior to use in equation 5.2. Hershfield suggested regional averaging to eliminate some of the variability caused by local topographic features. However, the stations with records for 50 years or more were so widely separated that regional averaging would have been difficult and probably meaningless.

Direct application of equation 5.2 to obtain point PMP estimates, (considered equivalent to 10-mi^2 (26-km^2) values), is not recommended. There is no completely objective method for determining K. Different investigators have suggested different values for the same or similar regions. Some statistical PMP estimates have been exceeded by record storm amounts from supplementary rainfall surveys. Our use of equation 5.2 in this study, as in others, is solely to provide another comparison of the overall level of PMP. Other attempts to apply the statistical approach, and the problems encountered, are given by Lockwood (1967) for studies in Malaya and Dhar et al.(1975) in India.

5.9 Hypothesized Severe Tropical Cyclone

Some of the most intense general rainfalls for the Southwest States have resulted from tropical cyclones. The September 1970 event is the outstanding example. Pyke (1975) has speculated on the possibility of much more intense rains from such a storm assuming several optimum conditions. It would be a good check on our PMP to consider rains from such a storm. Evaluation of a storm of this intensity however, would require considerable speculation; e.g., on the extent that a hurricane circulation could be maintained into the study region and on the upwind terrain effects depleting the moisture (fueling) for the storm.

We have taken a somewhat different approach. This was to start with PMP based on the greatest known rainfall from a tropical cyclone in the United States and make adjustments in transposing it to our study region. We then compare results with our PMP. Considerable meteorological discussion is given in the companion volume (Schwarz and Hansen 1978) concerning the hypothetical storm. This is not repeated here.

5.9.1 Transposition and Adjustment of PMP Based on the Yankeetown, Fla. Storm of September 5-6, 1950

The most intense rainfall of record for the United States from a tropical cyclone is the Yankeetown, Fla., event of September 5-6 1950 (Gentry 1951). This storm gave 38.7 inches (983 mm) of rain in 24 hours. The 10-mi^2 (26-km^2) estimate for the Gulf of Mexico coast, based on this storm, is 47.1 inches (1196 mm) (Schreiner and Riedel 1978). We adjusted this PMP value for occurrence in our study region. As a starting place, we chose a point off the Baja California coast (28°N, 115°W) as a location for optimum rain. This location would not include depletion (or intensification) for terrain and would allow a large sea surface for fueling the storm.

Sea surface temperature represents a measure of moisture potential for fueling tropical cyclones. Sea surface temperatures that are exceeded 5% of the time in the warmest month (National Oceanic Atmosphereic Administration 1973), were considered a fairly stable index. A value of 87°F (31°C) is obtained for the moisture source of the Yankeetown storm, compared to 74°F (23°C) near 28°N off Baja California. The ratio of precipitable water for a saturated atmosphere associated with a 1000-mb (100-kPa) temperature of 74°F (23°C) to one of 87°F (31°C) is 0.45. Adjusting the sea surface temperatures downward by 5°F (3°C) at both locations, thereby giving realistic 12-hr persisting 1000-mb (100-kPa) dew points, results in approximately the same reduction for differences in moisture potential.

This gives us an adjusted 24-hr value of 25.9 inches (658 mm) at 28°N, 115°W. We then applied a distance-from-coast adjustment (Schwarz 1965, 1973, and Schreiner and Riedel 1978) in order to obtain values within the study region. This adjustment is based on the decrease inland in nonorographic tropical storm rainfalls of record along the gulf and east coasts of the United States. Table 5.2 shows the percentage reduction with distance inland and the reduced values. These reduced values are also shown on the left side of the hypothesized track in figure 5.10. For comparison, this report's 1000-mb (100-kPa) convergence PMP values are shown plotted to the right of the track in the figure. The distance-from-coast reduced values are higher than the convergence PMP estimates from chapter 2 at every point along the track. The greatest differences are near the southern border of Arizona close to the Gulf of California. At 700 n.mi. (1296 km), there is almost no difference.

There are at least three factors not accounted for that would tend to reduce these hypothesized tropical-storm rain values. These are:

a. Depletion of rainfall upwind of any location, including the starting point by mountain barriers in the Baja California peninsula.

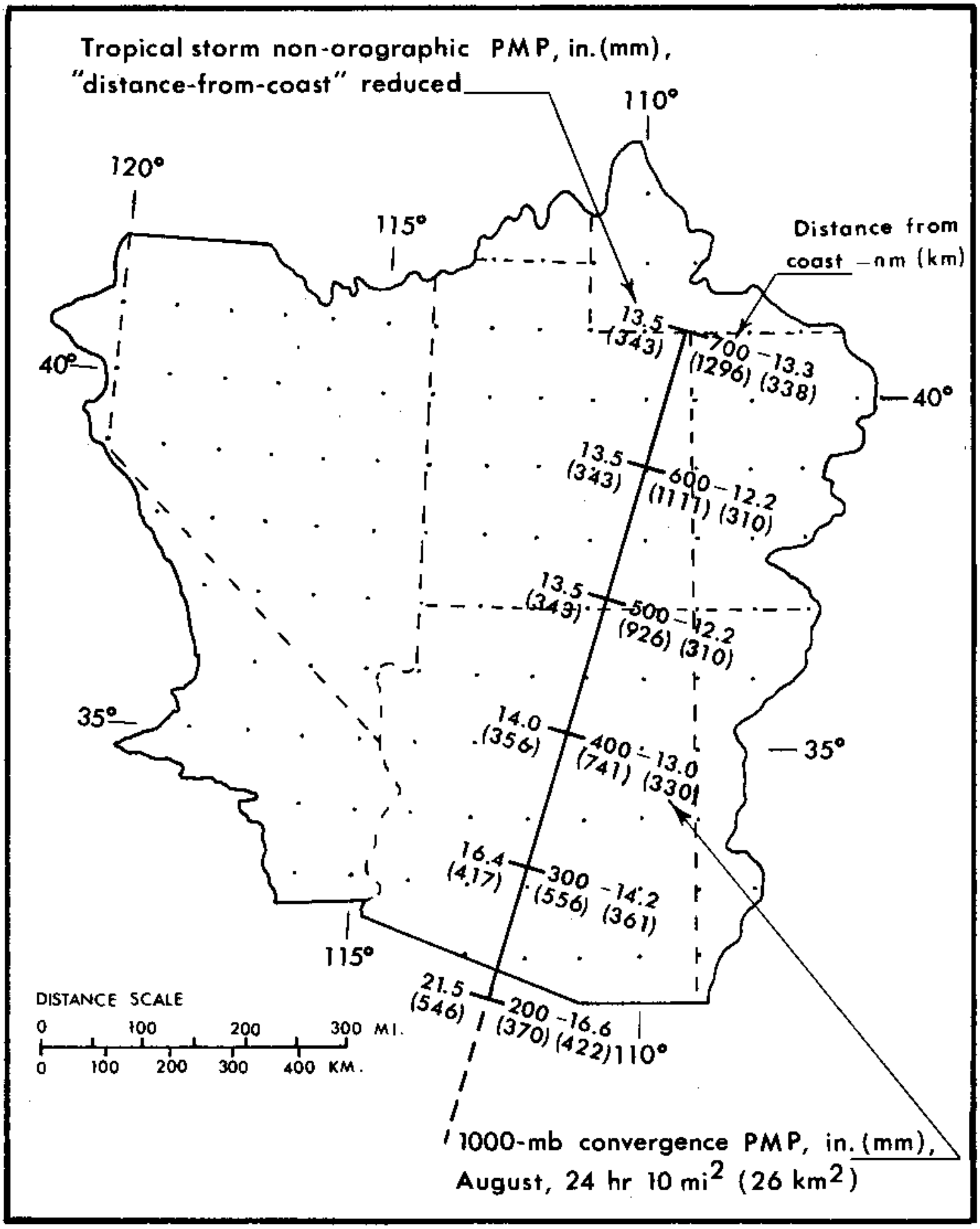


Figure 5.10--Distance-from-coast reduced tropical storm nonorographic PMP compared with 1000-mb (100-kPa) convergence PMP for August, 10 mi² (26 km²) 24 hr.

Table 5-2.--Adjustment of tropical storm PMP for distance-from-coast

Distance from coast n. mi.	(km)	Percent of Coastal Value	Adjusted rain in.	(mm)
0	0	100	25.9	(658)
100	185	96	24.6	(625)
200	370	83	21.5	(546)
300	556	63	16.4	(417)
400	741	54	14.0	(356)
500	926	52	13.5	(343)
600	1111	52	13.5	(343)
700	1296	52	13.5	(343)

b. Dampening effects of mountains on tropical cyclone circulation, assuming that maximum rainfall is produced by organized storms.

c. Effects of changing the speed of forward motion of the hypothetical tropical cyclone. (The Yankeetown storm was a slow-moving and looping storm that concentrated the rainfall. Such storm movement has not been duplicated off the Baja California coast.)

However, there is at least one factor that might contribute to even higher results than computed here. This is higher sea-surface temperatures than the 5% level postulated.

The authors believe that the combined effects of the three reducing factors outweigh the effect of higher sea surface temperatures. A hypothetical intense tropical cyclone moving northward over the Gulf of California, though taking advantage of the higher sea surface temperatures, would suffer considerably from the effects of the terrain and mountains on the circulation.

The authors further believe that the rainfall extremes determined from the generalized PMP study adequately allow for rain from a hypothesized severe tropical cyclone event in the Southwestern States.

5.10 Conclusion on PMP Checks

A variety of checks have been presented in this chapter on the general level of PMP. We conclude that the results show that the PMP and its seasonal, geographical, areal, and durational variations are appropriate and consistent.

6. PROCEDURES FOR COMPUTING PMP

6.1 Introduction

For estimating general-storm PMP for a specific drainage the maps, charts, and tables required are in chapters 2 and 3. A stepwise procedure for using these materials is given here with a computation form, table 6.1. This is followed by an example of the computations for a selected drainage (table 6.2).

The stepwise procedure and computation form are set up to give general-storm PMP for a given month. If the highest value over all months (called the "all-season" PMP) is needed, it may be necessary to compute PMP for several months and to then select the highest value.

The local-storm PMP for small drainages described in chapter 4 should be compared with general-storm PMP for any drainage and the most critical values selected. Depending on hydrologic characteristics of a particular drainage, its location, size, and the problem at hand, a 500-mi^2 (1,295-km^2) local storm, well placed on a drainage larger than 500 mi^2, may be the more critical of the two storm types. A step-wise procedure is given (sec. 6.3) for computing local-storm PMP. Part A gives the drainage average PMP while part B gives the areal distribution of PMP over the drainage. A computation form is provided in table 6.3, for computing these estimates. Table 6.4 is an example of these computations.

Local-storm PMP also covers the Pacific drainage of California. General-storm PMP for this region is given in HMR No. 36, with revisions (U.S. Weather Bureau 1969).

The procedures have been developed to give PMP in tenths of inches. Although in some instances it may be possible to discriminate values from figures and tables to hundredths of an inch or fractions of a percent, PMP estimates should be rounded to the nearest tenth of an inch.

6.2 Steps for Computing General-Storm PMP for a Drainage

A. Convergence PMP. The steps correspond to those in table 6.1.

1. Obtain drainage average 1000-mb (100-kPa) 24-hr 10-mi^2 (26-km^2) convergence PMP for month of interest from one of figures 2.5 to 2.16.

2. Obtain the 1000-mb (100-kPa) 24-hr 10-mi^2 (26-km^2) convergence PMP reduction factor for effective barrier and elevation in percent from figure 2.18.

3. Step 1 value times step 2 value gives barrier-elevation reduced 24-hr 10-mi^2 (26-km^2) convergence PMP average for the drainage.

4. Determine drainage 6/24-hr ratio for month of interest from figures 2.25 and 2.27. Enter table 2.7 with this ratio to obtain 6-, 12-, 18-, 24-, 48-, and 72-hr values in % of the 24-hr value.

5. Step 3 value times percents from step 4 provides convergence PMP for durations of step 4 for 10 mi^2 (26 km^2).

6. Incremental 10-mi^2 (26-km^2) convergence PMP is obtained by successive subtraction of values in step 5.

7. Areal reduction in percent for drainage area is obtained from figure 2.28 or 2.29 for the month of interest.

8. Values from step 6 times corresponding percents from step 7 are the areally reduced incremental convergence PMP in inches (mm).

9. Accumulation of incremental values from step 8 gives drainage average convergence component PMP for 6, 12, 18, 24, 48 and 72 hours.

B. Orographic PMP

1. Drainage average orographic PMP index for 24 hours 10 mi^2 (26 km^2) is read from one of figures 3.11a to d (foldout pages).

2. Areal reduction factor in percent for drainage size is read from figure 3.20.

3. To get seasonal adjustment, locate drainage on map for month of interest, figures 3.12 to 3.17, and read average percent for the drainage.

4. Areally and seasonally adjusted 24-hr orographic PMP in inches (mm) is obtained by multiplying values from step 1 by percents from steps 2 and 3.

5. Durational variation of orographic PMP in percent of the 24-hr value for 6, 12, 18, 24, 48, and 72 hours is read from table 3.9, which is entered with the latitude of the drainage (to the nearest 1°).

6. Orographic PMP in inches (mm) for listed durations results from multiplication of values in step 4 by corresponding values in step 5.

C. Total PMP

1. Add corresponding convergence and orographic PMP values in steps A9 and B6.

2. If PMP values are required for intermediate durations, plot a smooth curve and interpolate.

3. Compare with the local-storm PMP.

Table 6.2 shows an example of the computation of general-storm PMP for the month of October for the Humboldt River drainage above Devil's Gate damsite in Nevada. The table is self-explanatory.

6.3 Steps for Computing Local-Storm PMP

A. Drainage Average Depth Local-Storm PMP. Steps correspond to those in table 6.3A.

Use steps of section 6.3B if areal distribution within drainage is required.

Step

1. Locate drainage on figure 4.5 and read interpolated average PMP value for 1 hour 1 mi^2 (2.6 km^2) in inches (mm).

2. If the lowest elevation within the drainage is above 5,000 feet (1,524 m), decrease the PMP value from step 1 by 5% for each 1,000 feet (305 m) or proportionate fraction thereof above 5,000 feet (1,524 m). This gives elevation adjusted drainage average 1-hr 1-mi^2 (2.6-km^2) PMP.

3. Use figure 4.7 to find the 6/1-hr ratio for the drainage location.

4. Enter table 4.4 with the ratio from step 3 to obtain percentage durational variation.

5. Multiply each of the percentages of step 4 by the 1-hr PMP from step 2 to obtain PMP for 1/4 hr to 6 hours.

6. Enter the abscissa of figure 4.9 with the size of the drainage to obtain the areal reduction for each duration in terms of percent of 1-mi^2 (2.6-km^2) PMP.

7. Multiply the areal reduction percentages from step 6 by the PMP values from step 5 to obtain areally reduced PMP.

8. Determine the incremental PMP values by successive subtraction of values in step 7.

9. Arrange the hourly incremental values from step 8 in one of the time sequences shown in table 4.7. Use table 4.8 for sequence of 4 highest 15-minute increments.

Table 6.4A is an example of local-storm PMP computation for Sycamore Creek, Arizona.

B. Areal Distribution of Local-Storm PMP Within Drainage. The following steps are recommended for computing local-storm PMP and its areal distribution.

Step

1. Overlay a tracing of the drainage outline (adjusted to 1:500,000 scale) on figure 4.10. Rotate the outline to obtain the maximum rain volume in the drainage. (For particular problems, other placements may be hydrologically more critical.)

2. Note the isohyets that lie within the drainage.

3. Locate drainage on figure 4.5 and read interpolated PMP value for 1 mi^2 (2.6 km^2) in inches (mm).

4. If the lowest elevation within the drainage is above 5,000 feet (1,524 m) decrease the PMP value from step 3 by 5% for each 1,000 feet (305 m) or proportionate fraction thereof above 5,000 feet (1,524 m).

5. Use figure 4.7 to find the 6/1-hr ratio for the drainage.

6. Enter table 4.5 with 6/1-hr ratio of step 5 to obtain isohyetal labels for the 4 highest 15-min PMP increments in percent of 1-hr, 1-mi^2 (2.6-km^2) PMP.

7. Enter table 4.6 with 6/1-hr ratio of step 5 to obtain isohyetal labels for the 2nd highest to 6th highest (the lowest) 1-hr incremental PMP values in percent of 1-hr, 1-mi^2 (2.6-km^2) PMP.

8. Multiply the isohyetal percentages for each PMP increment from step 6 (for highest 1-hr PMP and 15-min incremental PMP) and step 7 (2nd to 6th highest 1-hr PMP) by the 1-hr, 1-mi^2 (2.6-km^2) PMP value from step 4. The results are incremental PMP isohyetal labels in inches (mm).

9. Arrange the hourly incremental values in one of the time sequences of table 4.7. Use table 4.8 for the sequence of 4 highest 15-min increments.

Note: An average depth equal to the value of the last isohyet (J) may be used for any portion of the drainage not covered by the isohyetal pattern.

Table 6.4B is an example of computation of local-storm PMP and its areal distribution for Sycamore Creek, Arizona.

Table 6.1.--General-storm PMP computations for the Colorado River and Great basin

Drainage ______________________ Area__________ mi^2 (km^2)

Latitude _________, Longitude ___ of basin center

Month _________

Step		6	12	18	24	48	72	
		Duration (hrs)						
A.	**Convergence PMP**							
1.	Drainage average value from one of figures 2.5 to 2.16 ___in. (mm)							
2.	Reduction for barrier-elevation [fig. 2.18] ___%							
3.	Barrier-elevation reduced PMP [step 1 X step 2] ___in. (mm)							
4.	Durational variation [figs. 2.25 to 2.27 and table 2.7].	___	___	___	___	___	___	%
5.	Convergence PMP for indicated durations [steps 3 X 4]	___	___	___	___	___	___	in. (mm)
6.	Incremental 10 mi^2 (26 km^2) PMP [successive subtraction in step 5]	___	___	___	___	___	___	in. (mm)
7.	Areal reduction [select from figs. 2.28 and 2.29]	___	___	___	___	___	___	%
8.	Areally reduced PMP [step 6 X step 7]	___	___	___	___	___	___	in. (mm)
9.	Drainage average PMP [accumulated values of step 8]	___	___	___	___	___	___	in. (mm)
B.	**Orographic PMP**							
1.	Drainage average orographic index from figure 3.11a to d. ___ in.(mm)							
2.	Areal reduction [figure 3.20] ___%							
3.	Adjustment for month [one of figs. 3.12 to 3.17] ___%							
4.	Areally and seasonally adjusted PMP [steps 1 X 2 X 3] ___in. (mm)							
5.	Durational variation [table 3.6]	___	___	___	___	___	___	%
6.	Orographic PMP for given durations [steps 4 X 5]	___	___	___	___	___	___	in. (mm)
C.	**Total PMP**							
1.	Add steps A9 and B6	___	___	___	___	___	___	in. (mm)
2.	PMP for other durations from smooth curve fitted to plot of computed data.							
3.	Comparison with local-storm PMP (see sec. 6.3).							

Table 6.2.--Example computation of general-storm PMP.

Drainage *Humboldt R.(above Devils Gate), Nevada* Area ________ mi² (km²)
Latitude *41° 20'*, Longitude *115°48* of basin center
Month *Oct.*

Step			6	12	18	24	48	72	
			Duration (hrs)						
A.	Convergence PMP								
1.	Drainage average value form one of figures 2.5 to 2.16	*9.2* in. ~~(mm)~~							
2.	Reduction for barrier-elevation [fig. 2.18]	*50* %							
3.	Barrier-elevation reduced PMP [step 1 X step 2]	*4.6* in. ~~(mm)~~							
4.	Durational variation [figs. 2.25 to 2.27 and table 2.7].		*62*	*82*	*93*	*100*	*119*	*129*	%
5.	Convergence PMP for indicated durations [steps 3 X 4]		*2.8*	*3.8*	*4.3*	*4.6*	*5.5*	*5.9*	in. ~~(mm)~~
6.	Incremental 10 mi² (26 km²) PMP [successive subtraction in step 5]		*2.8*	*1.0*	*0.5*	*0.3*	*0.9*	*0.4*	in. ~~(mm)~~
7.	Areal reduction [select from figs. 2.28 and 2.29]		*63*	*85*	*93*	*98*	*100*	*100*	%
8.	Areally reduced PMP [step 6 X step 7]		*1.8*	*0.8*	*0.5*	*0.3*	*0.9*	*0.4*	in. ~~(mm)~~
9.	Drainage average PMP [accumulated values of step 8]		*1.8*	*2.6*	*3.1*	*3.4*	*4.3*	*4.7*	in. ~~(mm)~~
B.	Orographic PMP								
1.	Drainage average orographic index from figure 3.11a to d.	*3.3* in. ~~(mm)~~							
2.	Areal reduction [figure 3.20]	*82* %							
3.	Adjustment for month [one of figs. 3.12 to 3.17]	*100* %							
4.	Areally and seasonally adjusted PMP [steps 1 X 2 X 3]	*2.7* in. ~~(mm)~~							
5.	Durational variation [table 3.6]		*29*	*56*	*79*	*100*	*160*	*189*	%
6.	Orographic PMP for given durations [steps 4 X 5]		*0.8*	*1.5*	*2.1*	*2.7*	*4.3*	*5.1*	in. ~~(mm)~~
C.	Total PMP								
1.	Add steps A9 and B6		*2.6*	*4.1*	*5.2*	*6.1*	*8.6*	*9.8*	in. ~~(mm)~~
2.	PMP for other durations from smooth curve fitted to plot of computed data.								
3.	Comparison with local-storm PMP (see sec. 6.3).								

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

Drainage ______________________ Area __________ mi^2 (km^2)
Latitude __________ Longitude __________ Minimum Elevation _____ ft (m)

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. __________ in. (mm)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. __________ %

   b. Multiply step 1 by step 2a. __________ in. (mm)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. __________

	Duration (hr)									
	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	___	___	___	___	___	___	___	___	___	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	___	___	___	___	___	___	___	___	___	in. (mm)
6. Areal reduction [fig. 4.9].	___	___	___	___	___	___	___	___	___	%
7. Areal reduced PMP [steps 5 X 6].	___	___	___	___	___	___	___	___	___	in. (mm)
8. Incremental PMP [successive subtraction in step 7].				___	___	___	___	___	___	in. (mm)
	___	___	___	___ } 15-min. increments						

9. Time sequence of incremental PMP according to:

   Hourly increments [table 4.7]. ___ ___ ___ ___ ___ ___ in. (mm)

   Four largest 15-min. increments [table 4.8]. ___ ___ ___ ___ in. (mm)

Table 6.3B.--Local-storm PMP computation, Colorado River and Great Basin, and California drainages. (Giving areal distribution of PMP).

Steps correspond to those in sec. 6.3B.

1. Place idealized isohyetal pattern [fig. 4.10] over drainage adjusted to 1:500,000 scale to obtain most critical placement.
2. Note the isohyets within drainage.
3. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. ________ in. (mm)
4. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m), 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. ________ %

   b. Multiply step 3 by step 4a. ________ in. (mm)
5. Average 6/1-hr ratio for drainage [fig. 4.7]. ________
6. Obtain isohetal labels for 15-min incremental and the highest PMP from table 4.5 corresponding 6/1-hr ratio of step 5.

PMP Increment	Isohyet A	B	C	D	E	F	G	H	I	J	
Highest 1-hr											
Highest 15-min.											
2nd "											
3rd "											in %
4th "											

7. Obtain isohyetal labels in % of 1-hr PMP for 2nd to 6th highest hourly incremental PMP values from table 4.6 using 6/1-hr ratio of step 5.

2nd Highest 1-hr PMP											
3rd "											
4th "											in %
5th "											
6th "											

8. Multiply steps 6 and 7 by step 4b to get incremental isohyetal labels of PMP.

Highest 15-min.											
2nd "											
3rd "											
4th "											
Highest 1-hr											in in. (mm)
2nd "											
3rd "											
4th "											
5th "											
6th "											

9. Arrange values of step 8 in time sequence [tables 4.7 and 4.8].

Table 6.4A.--Example of computation of local-storm PMP. Average values for the drainage.

Drainage *Sycamore Ck. (above Verde River), Arizona* Area *360* mi^2 (~~km^2~~)
Latitude *34° 53'* Longitude *112° 08'* Minimum Elevation *3850* ft (~~m~~)

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. — *10.1* in. (~~mm~~)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. — *100* %

   b. Multiply step 1 by step 2a. — *10.1* in. (~~mm~~)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. — *1.2*

	Duration (hr)									
	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	*74*	*89*	*95*	*100*	*110*	*115*	*118*	*119*	*120*	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	*7.5*	*9.0*	*9.6*	*10.1*	*11.1*	*11.6*	*11.9*	*12.0*	*12.1*	in. (~~mm~~)
6. Areal reduction [fig. 4.9].	*16*	*20*	*23*	*26*	*30*	*34*	*37*	*38.5*	*40*	%
7. Areal reduced PMP [steps 5 X 6].	*1.2*	*1.8*	*2.2*	*2.6*	*3.3*	*3.9*	*4.4*	*4.6*	*4.8*	in. (~~mm~~)
8. Incremental PMP [successive subtraction in step 7].				*2.6*	*0.7*	*0.6*	*0.5*	*0.2*	*0.2*	in. (~~mm~~)
	1.2	*0.6*	*0.4*	*0.4*	} 15-min. increments					

9. Time sequence of incremental PMP according to:

   Hourly increments [table 4.7]. — *0.2* *0.6* *2.6* *0.7* *0.5* *0.2* in. (~~mm~~)

   Four largest 15-min. increments [table 4.8]. — *1.2* *0.6* *0.4* *0.4* in. (~~mm~~)

Table 6.4B.--Example computation of local-storm PMP. Areal distribution over the drainage.

Steps correspond to those in sec. 6.3B.

1. Place idealized isohyetal pattern [fig. 4.10] over drainage adjusted to 1:500,000 scale to obtain most critical placement.

2. Note the isohyets within drainage.

3. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 10.1 in. ~~(mm)~~

4. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m), 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. 100 %

   b. Multiply step 3 by step 4a. 10.1 in. ~~(mm)~~

5. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.2

6. Obtain isohyetal labels for 15-min PMP from table 4.5 corresponding 6/1-hr ratio of step 5 and labels for highest 1 hr.

	Isohyet										
PMP Increment	A	B	C	D	E	F	G	H	I	J	
Highest 1-hr	100	82	58	44	32	23	16	13	12	11	
Highest 15-min.	74	56	32	21	14	8	7	6	5	4	
2nd "	15	15	15	12	9	6	4	3	3	3	
3rd "	6	6	6	6	5	5	3	2	2	2	in %
4th "	5	5	5	5	4	4	2	2	2	2	

7. Obtain isohyetal labels in % of 1-hr PMP for 2nd to 6th highest hourly incremental PMP values from table 4.6 using 6/1-hr ratio of step 5.

2nd Highest 1-hr	11	11	11	11	10	8	7	5	5	5	
3rd "	4	4	4	4	4	4	4	4	4	4	
4th "	3	3	3	3	3	3	3	3	3	3	in %
5th "	2	2	2	2	2	2	2	2	2	2	
6th "	1	1	1	1	1	1	1	1	1	1	

8. Multiply steps 6 and 7 by step 4b to get incremental isohyetal labels of PMP.

Highest 15-min.	7.5	5.7	3.2	2.1	1.4	0.8	0.7	0.6	0.5	0.4	
2nd "	1.5	1.5	1.5	1.2	0.9	0.6	0.4	0.3	0.3	0.3	
3rd "	0.6	0.6	0.6	0.6	0.5	0.5	0.3	0.2	0.2	0.2	
4th "	0.5	0.5	0.5	0.5	0.4	0.4	0.2	0.2	0.2	0.2	
Highest 1-hr	10.1	8.3	5.9	4.4	3.2	2.3	1.6	1.3	1.2	1.1	in in. ~~(mm)~~
2nd "	1.1	1.1	1.1	1.1	1.0	0.8	0.7	0.5	0.5	0.5	
3rd "	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
4th "	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
5th "	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
6th "	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	

9. Arrange values of step 8 in time sequence [tables 4.7 and 4.8].

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